CLIVAR Indian Ocean (I9N) 2007 Cruise
Readme File

Class of Data: Surface ocean carbon dioxide concentrations

Dataset Identifier: Expo Code 33RR20070322

Statement of how to cite dataset:

CLIVAR I9N website: http://www.aoml.noaa.gov/ocd/gcc/clivari9n

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Cruise Information:

This cruise was part of the CLIVAR/CO2 repeat hydrography program (see http://ushydro.ucsd.edu/). The Scripps Institution of Oceanography's Research Vessel Roger Revelle departed Fremantle, Australia on 22 March 2007 with the I9N transect passing through four distinct climatic regimes: the subtropical gyre, the Indonensian Throughflow plume, the equatorial regime and the Bay of Bengal. The cruise ended in Phuket, Thailand on 1 May 2007 having completed all the WOCE 1995 I9N line. Underway surface pCO2, temperature, conductivity, dissolved oxygen, fluorometer, meteorological and multibeam acoustical bathymetric measurements were made.

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Timestamp for initial submission of dataset: 5/5/08

Timestamp for the most recent update of dataset: 5/5/08

Timestamp period the dataset refers to: 3/22/2007 - 4/28/2007

Geographic area the dataset refers to:

35 S to 20 N
80 E to 115 E

List of variables included in this dataset:

COLUMN	HEADER	EXPLANATION
1.	GROUP/SHIP:	AOML_Revelle.
2.	CRUISE_DESIGNATION:	IO9N(2007)_33RR20070322
3.	JD_GMT:	Decimal year day.
4.	DATE_DDMMYYYY:	The date format has been changed from previous files to conform with the IOCCP recommendations.
5.	TIME_HH:MM:SS:	GMT time. Local time = GMT +8/+7 hours.
6.	LAT_DEC_DEGREE:	Latitude in decimal degrees (negative values are in the southern hemisphere).
7.	LONG_DEC_DEGREE:	Longitude in decimal degrees (negative values are in the western hemisphere).
8.	xCO2W_PPM:	Mole fraction of CO2 (dry) in the headspace equilibrator at equilibrator temperature (Teq) in parts per million.
9.	xCO2A_PPM:	Mole fraction of CO2 in air in parts per million.
10.	PRES_EQUIL_hPa:	Barometric pressure in the lab in hectopascals(1 hectopascal = 1 millibar).
11.	PRES_SEALEVEL_hPa:	Barometric pressure from ship's barometer, corrected to sea level in hectopascals (1 hectopascal = 1 millibar).
12.	EQTEMP_C:	Temperature in equilibrator water in degrees centigrade. Temperature in equilibrator measured with a calibrated thermistor.
13.	SST(TSG)_C:	Temperature from the ship's thermosalinograph in degrees centigrade.
14.	SAL(TSG)_PERMIL:	Salinity from the ship's thermosalinograph on the Practical Salinity Scale.
15.	WATER_FLOW_L/MIN:	Water flow through equilibrator in liters per minute.

16. GASFLOW_IR_ML/MIN: Gas flow through the Licor infrared analyzer before the flow is stopped in milliliters per minute.

17. TEMP_IR_C: Temperature of the Licor infrared analyzer sample cell in degrees centigrade.

18. PRES_IR_hPa: Pressure in the Licor infrared analyzer in hectopascals. NOTE: There is no pressure sensor in the Licor but since it is vented to atmosphere prior to measurement, this value is the same as the pressure in the lab (number 10 above). (1 hectopascal = 1 millibar).

19. SHIP_HEADING_TRUE_DEGREE: Ship's heading from ship's navigation system in degrees with 0 = North and 90 = East.

20. SHIP_SPEED_KNOT: Ship's speed from ship's navigation system in knots.

21. WIND_DIR_REL_DEGREE: Wind direction relative to the ship from ship's navigation system in degrees with 0 = from the bow and 90 = from starboard.

22. WIND_SPEED_REL_M/S: Wind speed relative to the ship from ship's navigation system in meters per second.

23. fCO2W@SST_uATM: Fugacity of CO2 in sea water in microatmospheres.

24. QC_FLAG_WATER: Quality control flag for sea water xCO2 and fCO2 values with 2 = good value, 3 = questionable value, 4 = bad value, and 9 = no measurement taken.

25. fCO2a_uATM: Fugacity of CO2 in air in microatmospheres.

26. QC_FLAG_AIR: Quality control flag for air xCO2 and fCO2 with 2 = good value, 3 = questionable value, 4 = bad value, and 9 = no measurement taken.

27. dfCO2_uATM: Sea water fCO2 - air fCO2 in microatmospheres. This uses the average air value for the current hour.

28. FLUORO_uG/L: Reading from the fluorometer in micrograms per liter. There is no fluorometer data for this cruise.

29. WIND_SPEED_TRUE_M/S: True wind speed in meters per second.

30. WIND_DIR_TRUE_DEGREE: True wind direction in degrees were 0 = North and 90 = East.

31. AIR_TEMP_C: Outside air temperature from ship's computer system in degrees centigrade.

The following fields have been QC'ed by the CO2 group:

GROUP_SHIP
CRUISE
JD_GMT
DATE_DDMMYYYY
TIME_HH:MM:SS
LAT_DEC_DEGREE
LONG_DEC_DEGREE
xCO2W_PPM
xCO2A_PPM
PRES_EQUIL_hPa
EQTEMP_C
WATER_FLOW_L/MIN
GASFLOW_IR_ML/MIN
TEMP_IR_C
PRES_IR_hPa
fCO2W@SST_uATM
QC_FLAG_WATER

The following fields are from the ship's onboard systems and the quality of this data cannot be verified:

PRES_SEALEVEL_hPa
SST(TSG)_C
SAL(TSG)_PERMIL
SHIP_HEADING_TRUE_DEGREE
SHIP_SPEED_KNOT
WIND_DIR_REL_DEGREE
WIND_SPEED_REL_M/S
FLUORO_uG/L
WIND_SPEED_TRUE_M/S
WIND_DIR_TRUE_DEGREE
AIR_TEMP_C

CO2 ANALYTICAL SYSTEM:

The concentration of carbon dioxide (CO2) in surface ocean water is determined by measuring the concentration of CO2 in gas that is in contact with the water. Surface water is pumped from an inlet in the ship's bow to the equilibration chamber. The chamber contains a water spray head, an enclosed gaseous headspace (~ 850 ml), and a pool of seawater (~ 750 ml) that continuously overflows to a drain. As the water flows through the chamber, the dissolved gases (like CO2) partition between the water and the headspace. At equilibrium, the ratio of CO2 in the water and in the headspace is influenced most by temperature, and that relationship is known. By measuring the concentration of CO2 in the headspace and the temperature in the chamber, the partial pressure (or fugacity) of CO2 in the surface water can be calculated.

CALCULATIONS:

The mixing ratios of ambient air and equilibrated headspace air are calculated by fitting a second-order polynomial through the hourly averaged response of the detector versus mixing ratios of the standards. Mixing ratios of dried equilibrated headspace and air are converted to fugacity of CO2 in surface seawater and water saturated air in order to determine the fCO2. For ambient air and equilibrator headspace the fCO2a, or fCO2eq is calculated assuming 100% water vapor content:

$$fCO2a/eq = xCO2a/eq(P-pH2O)\exp(B11+2d12)P/RT$$

where fCO2a/eq is the fugacity in ambient air or equilibrator, pH2O is the water vapor pressure at the sea surface temperature, P is the atmospheric pressure (in atm), T is the SST or equilibrator temperature (in K) and R is the ideal gas constant (82.057 cm^3·atm·deg^-1·mol^-1). The exponential term is the fugacity correction where B11 is the second virial coefficient of pure CO2

$$B11 = -1636.75 + 12.0408T - 0.032795T^2 + 3.16528E-5\ T^3$$

and $d12 = 57.7 - 0.118\ T$

is the correction for an air-CO2 mixture in units of cm^3·mol^-1 (Weiss, 1974).

The calculation for the fugacity at SST involves a temperature correction term for the increase of fCO2 due to heating of the water from passing through the pump and through 5 cm ID PVC tubing within the ship. The water in the equilibrator is typically 0.2 °C warmer than sea surface temperature. The empirical temperature correction from equilibrator temperature to SST is outlined in Takahashi et al (1993):

$$fCO2w = fCO2eq\ \mathrm{Exp}(0.0423\ (SST-Teq))$$

INSTRUMENT DESIGN:

The general principle of instrumental design can be found in Wanninkhof and Thoning (1993), Ho et al. (1995), and Feely et al. (1998). The analyses are done with an infrared analyzer calibrated with three standard gases spanning the anticipated range of water and air values. The standard gases come from NOAA/CMDL in Boulder and are directly traceable to the WMO scale.

The standards used on the cruise are:

STANDARD	TANK #	CONCENTRATION	VENDOR
STD1	CA06827	284.71	CMDL
STD2	CA05334	380.98	CMDL
STD3	CA06380	448.29	CMDL

Salinity, SST, wind direction (both absolute and relative), wind speed (both absolute and relative), sealevel pressure, air temp, latitude and longitude data are from the ship's MET system log files. Ship speed and ship course are missing.

Sampling Cycle:
The system runs on an hourly cycle during which 3 standard gases, 3 air samples from the bow tower and 8 surface water samples (from the equilibrator head space) are analyzed on the following schedule:

Mins. after hour	Sample
3.5	Low Standard
7.5	Mid Standard
11.5	High Standard
16.24	Water
20.5	Water
25.2	Water
29.5	Water
33.5	Air
37.5	Air
41.5	Air
46.2	Water
50.5	Water
55.2	Water
59.5	Water

Units:
All xCO2 values are reported in parts per million (ppm) and fCO2 values are reported in microatmospheres (uatm) assuming 100 % humidity at the equilibrator temperature for fCO2w and for SST at fCO2a.

Estimated overall uncertainty of measurement:

The xCO2eq measurements are believed accurate to 1 ppm. The fCO2@SST measurements are believed to be precise to 2 ppm.

Bibliography:

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Ho, D. T., R. Wanninkhof, J. Masters, R. A. Feely and C. E. Cosca (1997). Measurement of underway fCO2 in the Eastern Equatorial Pacific on NOAA ships BALDRIGE and DISCOVERER, NOAA data report ERL AOML-30, 52 pp., NTIS Springfield.

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Weiss, R. F. (1970). The solubility of nitrogen, oxygen and argon in water and seawater. Deep-Sea Research 17: 721-735.

Weiss, R. F. (1974). Carbon dioxide in seawater: the solubility of a non-ideal gas. Mar. Chem. 2: 203-215.

Takahashi, T., J. Olafsson, J. G. Goddard, D. W. Chipman, and S. C.

Sutherland (1993). Seasonal variation of CO2 and nutrients in the high-latitude surface oceans: a comparative study, Global Biogeochem. Cycles, 7, 843-878.

DATA QC:

The questionable fCO2W@SST data for the following year days (JD) were removed (initialized to -999.99):

JD
83.514
83.907
83.910
83.913
83.917
88.345
95.372
95.375
95.386
95.389
95.393
95.396
95.407
95.410
95.413
95.417
96.532
96.538
98.741
99.372
100.288
100.354
102.220
104.327
104.413
104.616
105.369
106.312
106.324
106.413
106.514
106.518
109.312
110.407
110.417
111.407
111.437
113.410
113.889
113.893
115.407
115.434
116.312
116.348
116.372
116.410

116.510
116.604